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DEPARTMENT OF TRANSPORTATION

# PHYSICAL RESEARCH REPORT NO. 66

# INVESTIGATION OF BRIDGE APPROACH SPANS TO POPLAR STREET BRIDGE

MATERIALS & PHYSICAL RESEARCH

ILLINOIS DEPARTMENT OF TRANSPORTATION

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State of Illinois
DEPARTMENT OF TRANSPORTATION
Division of Highways
Bureau of Materials and Physical Research

# INVESTIGATION OF BRIDGE APPROACH SPANS TO POPLAR STREET BRIDGE

A Preliminary Study

by

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## SUMMARY

The findings of this study indicate that under normal circumstances problems may develop with certain pin-connected details that can result in major structural damage to the main supporting members of a bridge. The structural problems that have occurred with the bridges on the Poplar Street Complex are given as an example.

Observations of pin-connected bearings removed from the Poplar Street Complex show that rust can accumulate between the contact surfaces of the pin and the housing which can eventually seize the bearing. At several locations on the Poplar Street Complex, seizure of the bearings had resulted in web tearing, web buckling, separation between the bottom flange of the girder and the top bearing plate, and tearing of the bottom flange.

Laboratory tests of models similar to the bearing assemblies used on the Complex, indicate that the service life of this type of bearing could be substantially improved by using a case hardened pin and by lubricating the assembly with a heavy duty grease.

In conclusion, it appears that the use of pin-connected details subjected to large rotations and utilizing untreated, corrosive mild steels should be avoided for highway bridges. Consideration should be given to the use of elastomeric, TFE-elastomeric, and elastomeric pot-type bearings in the design of new structures.

Other structural problems that have developed with the Complex also indicate a need for further research on the overall behavior of two-girder systems under all modes of loading with major emphasis on the interaction between the diaphragms or floor beams and the main girders. The research should be oriented toward developing design details that would eliminate web cracking as found near the top of the fillet

weld connecting the bottom flange and the web, and just below the coped portion of the connecting plate. This research should include both straight and horizontally curved girder systems with both open and closed framing.

## INTRODUCTION

In late 1973, while making an inspection of the Poplar Street Complex, the Bridge Inspection Team from the Bureau of Maintenance discovered several serious problems relating to the main supporting members of the structures within the Complex. The results of their inspection are documented in a report dated February 1974.

Their inspection revealed over 40 different locations of major distress which had developed since the construction of the Complex. The major areas of distress were predominately located at the ends of the girders. The problems relating to the distressed areas consisted of either or a combination of web tearing, web buckling, separation between the bottom flange of the girders and the top bearing plate, and tearing of the bottom flange. Vertical cracks at the top of several concrete columns were also found during the inspection.

Design and maintenance engineers were concerned not only about the possibility of structural failure within the areas of known distress but also about the potential of future failures occurring at other locations. The Bridge and Traffic Structures Section of the Bureau of Design had made a study of the probable causes for the distress of the girders. Their findings are presented in a report dated June 1, 1974 entitled, "Investigation Report on Poplar Street Complex Bridges, East St. Louis, St. Clair County, Illinois."

It was concluded in the report that seized bearings had contributed to the types of distress involving web buckling and separation of the bottom flange and the top bearing plate. The Bureau of Materials and Physical Research was requested to make a study of the seized bearings to determine the cause for seizure and to prepare recommendations for correcting the problem.

This report presents the findings of the study and recommendations for resolving the problems associated with the seized bearings on the Poplar Street Complex. The need for further research to validate existing design theories and analysis of two-girder systems is also presented in this report.

Description of Poplar Street Complex

The Poplar Street Complex is one of the largest interchange systems in the State and is located on the east side of the Mississippi River in East St. Louis. It serves two Interstate Highways (FAI 55 and FAI 70) and three major U.S. routes which are combined to cross the Mississippi by the Poplar Street Bridge. The Complex contains over 260 approach spans which are mostly incorporated as a series of three- and four-span continuous units (Figure 1).

The structures for the Complex consist of curved, two-girder systems. A majority of the girders have a horizontal radius of approximately 1800 feet. The design is considered an open frame system which does not require lateral bracing at the bottom flange of the girders. Torsional resistance within the system is developed by interaction of the girders and the diaphragms or floor beams. Although some torsional resistance can be developed within the individual girders, this resistance is small and is normally neglected in the design of the system. The diaphragms or floor beams also support the stringers and the reinforced concrete deck which carries the traffic loads, and transfer the loads from the stringers to the main girders.

Field Test

Visual inspection of bearings at several locations indicated that little or no movement was occurring within the assemblies. Instrumentation was developed and installed at six locations to verify these observations and to determine if the distress was related to the problem of bearing seizure.

Two different measuring devices were installed to study the behavior of the bearings when they are subjected to expansive and contractural forces (Figure 2).

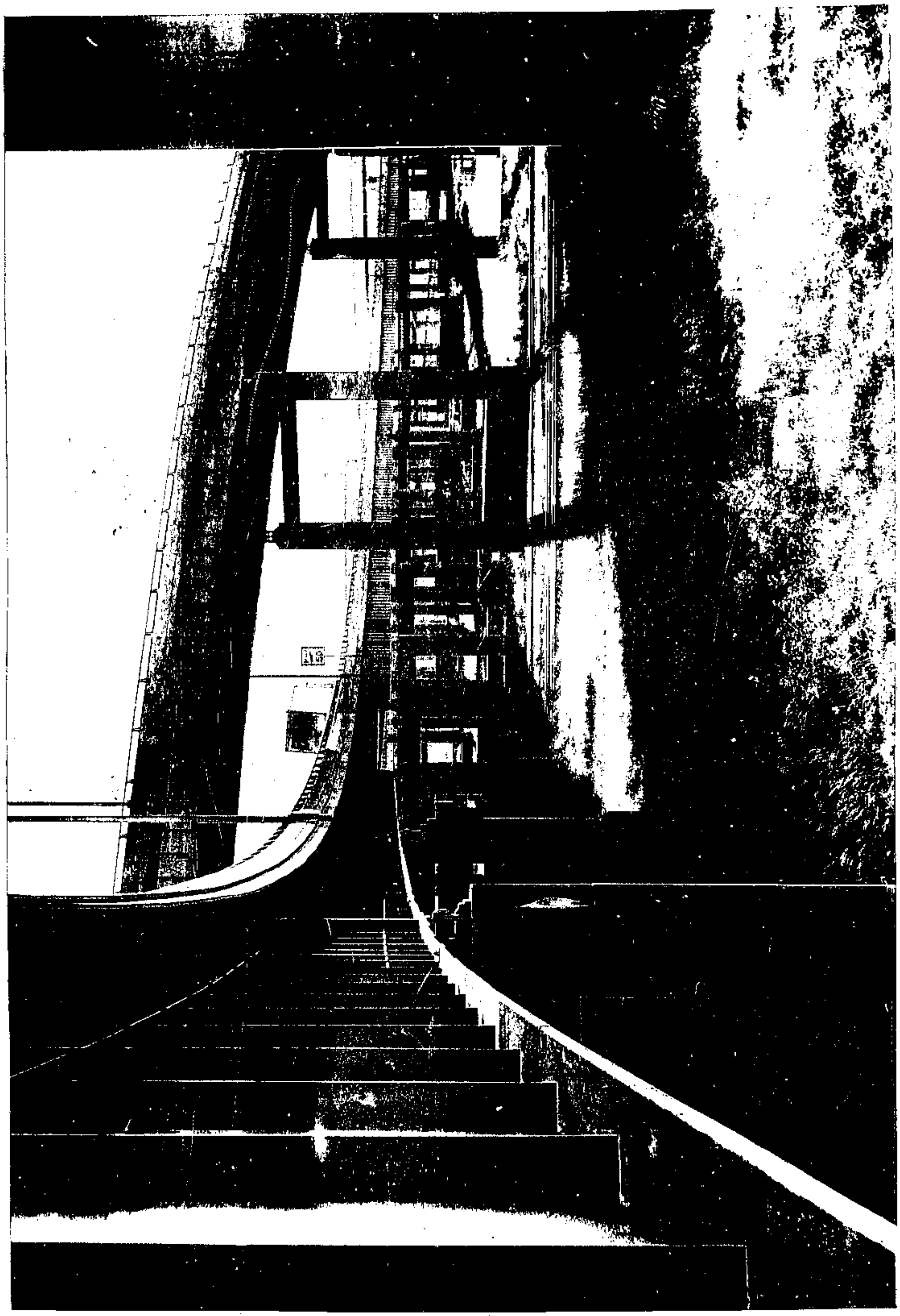


Figure 1. General view of Poplar Street Complex.

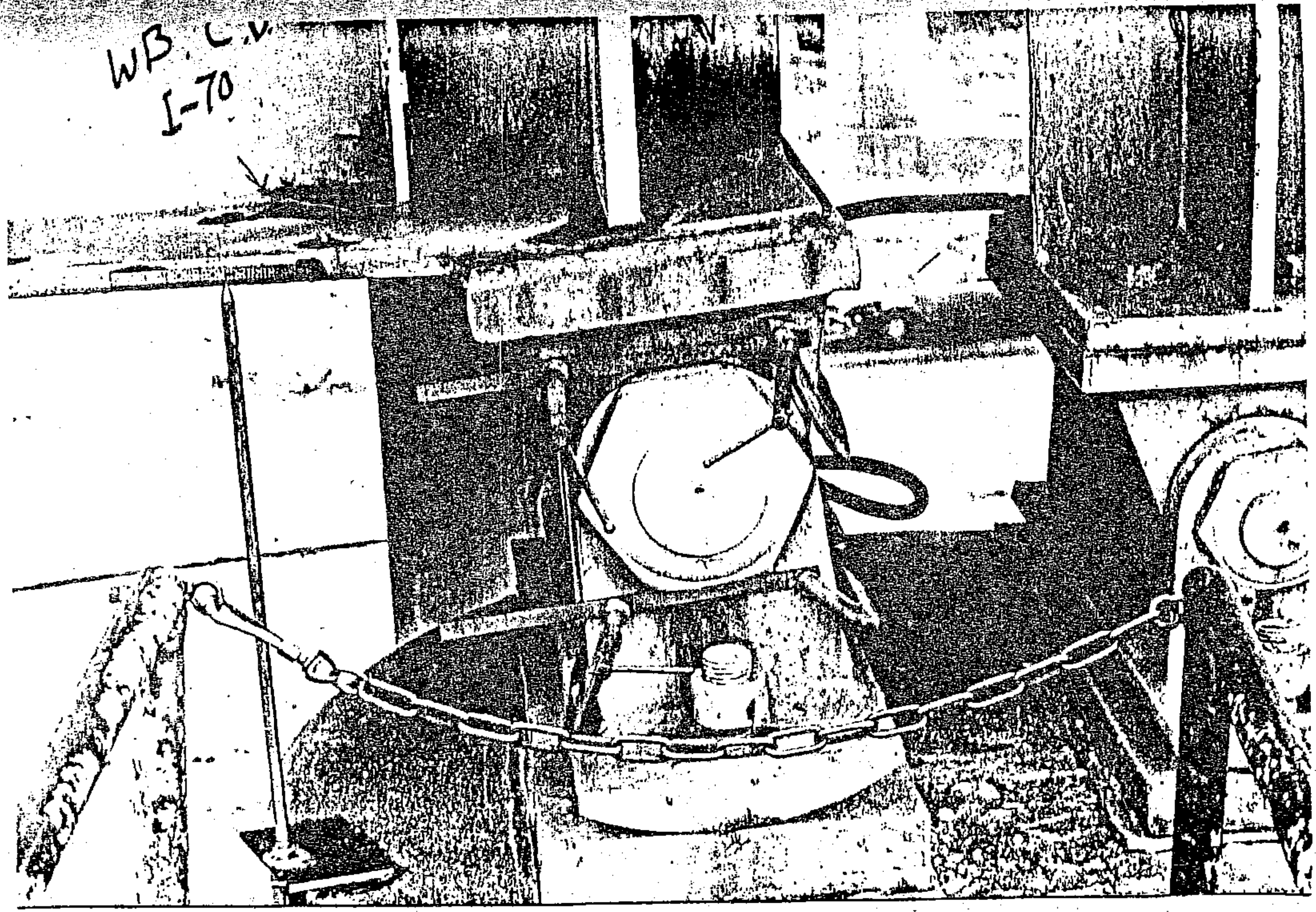



Figure 2. Instrumentation of seized bearing at Pier S-14.

One set of instrumentation consisted of two steel bars attached to the top and bottom bolsters of the pinned rocker assemblies to determine if the bearings were free to rotate. Reference points were established on the bars to measure the rotation of the bolsters about the pin.

The second set of instrumentation consisted of a scale fastened to the bottom flange of the girders and a pointed indicator attached to the face of the pier or the abutment cap. This device was used to measure relative movements occurring between the girder and the bearing seat of the substructure.

The rotation and expansion measurements are tabulated in Tables 1 and 2. The measurements in Table 1 taken between December 4 and 11, 1973, indicate little or no expansion or rotation occurring at the three locations identified as (1) the south bearing of Ramp B at the east abutment, (2) the south bearing of Ramp B at Pier S-14, and (3) the north bearing at Pier G-1. The data also show that the north bearing of Ramp C at the east abutment responded freely to expansion and rotational movements.

On January 30, 1974, it was decided to monitor the movements of the four bearings at the east abutments of both ramps B and C. The measurements are given in Table 2. The data show that the two bearings of Ramp C responded freely to expansion and rotational movements while no rotational movement was recorded for the south bearing of Ramp B. Some movement, which was about 35 percent of that occurring at the bearings for Ramp C, was recorded for the north bearing of Ramp B.

A summary of the movements of the bearings at the east abutment is shown in Figure 3 and 4. A plot of the measured rotations relative to the theoretical values indicates that little or no rotational movement is occurring at the south bearing of Ramp B, identified as bearing 2 (Figure 3). However, the measured expansions for the same bearing as shown in Figure 4 indicates that some movement had taken place between the girder and the abutment. It is believed that this movement was translated through the assembly by slippage between the rocker and the bottom base plate.

TABLE 1

EXPANSION AND ROTATION MEASUREMENTS FROM
DECEMBER 4, 1973 TO DECEMBER 11, 1973

| Reading Date | Reading Time | Temperature 1/ Reading | Temperature 1/ Difference | Measured Movements Between Girder and Substructure, in. 2/ Difference | Measured Rotational Movements of Bearing Assembly, in. 2/ Difference |
|---|---|---|---|---|---|
| | | Bearing Location: E. Abut. S. Brg. Ramp B | | | |
| 12-4-73 | 5:30 PM | 47° | - | - | - |
| 12-5-73 | 8:35 AM | 35° | -12° | - | +.01 |
| 12-10-73 | 11:30 AM | 26° | -9° | +.03 | +.01 |
| 12-10-73 | 2:50 PM | 30° | +4° | .00 | .00 |
| 12-10-73 | 5:35 PM | 31° | +1° | +.03 | +.01 |
| 12-11-73 | 7:45 AM | 31° | 0° | +.03 | .00 |
| | | Bearing Location: Pier S-14 Ramp B | | | |
| 12-4-73 | 2:30 PM | 55° | - | - | - |
| 12-5-73 | 9:22 AM | 34° | -21° | - | .00 |
| 12-10-73 | 12:45 PM | 26° | -8° | -.11 | .00 |
| | | Bearing Location: Pier G-1 | | | |
| 12-4-73 | 2:00 PM | 55° | - | - | - |
| 12-5-73 | 9:45 AM | 33° | -22° | 3/ | .00 |
| 12-10-73 | 1:35 PM | 26° | -7° | - | .00 |
| | | Bearing Location: E. Abut. N. Brg. Ramp C | | | |
| 12-4-73 | 5:50 PM | 47° | - | - | - |
| 12-5-73 | 8:45 AM | 34° | -13° | - | -.24 |
| 12-10-73 | 11:30 AM | 24° | -10° | -.10 | -.11 |
| 12-10-73 | 2:45 PM | 30° | +6° | +.05 | +.05 |
| 12-10-73 | 5:35 PM | 29° | -1° | -.03 | -.03 |
| 12-11-73 | 7:35 AM | 31° | +2° | -.08 | -.07 |

1/ Temperature of girder in shade.

2/ Differential movement from each preceding reading, (+) Expansion, (-) Contraction

3/ Expansion gage removed during repair of girder.

TABLE 2

EXPANSION AND ROTATION MEASUREMENTS FROM
JANUARY 30, 1974 TO FEBRUARY 6, 1974

| Date | Time | Temperature Reading | Temperature Difference | Measured Movements Between Girder and Substructure, in. Difference 1/ | Measured Rotational Movements of Bearing Assembly, in. Difference 1/ |
|---|---|---|---|---|---|
| Bearing No. 1 Location: E. Abut. N. Brg. Ramp B | | | | | |
| 1-30-74 | 1:30 PM | 53° 2/ | - | - | - |
| 1-31-74 | 8:30 AM | 44° | -9° | -.08 | -.03 |
| 2-1-74 | 7:45 AM | 29° | -15° | -.16 | -.13 |
| 2-4-74 | 7:50 AM | 16° | -13° | -.08 | -.03 |
| 2-6-74 | 8:00 AM | 44° | +28° | +.19 | +.13 |
| Bearing No. 2 Location: E. Abut. S. Brg. Ramp B | | | | | |
| 1-30-74 | 1:40 PM | 62° 2/ | - | - | - |
| 1-31-74 | 8:40 AM | 44° | -18° | -.08 | - |
| 2-1-74 | 7:45 AM | 29° | -15° | -.16 | .00 |
| 2-4-74 | 7:50 AM | 16° | -13° | -.09 | .00 |
| 2-6-74 | 8:00 AM | 44° | +28° | +.22 | +.06 |
| Bearing No. 3 Location: E. Abut. N. Brg. Ramp C | | | | | |
| 1-30-74 | 1:45 PM | 55° 2/ | - | - | - |
| 1-31-74 | 8:40 AM | 44° | -11° | -.06 | -.03 |
| 2-1-74 | 7:45 AM | 29° | -15° | -.24 | -.25 |
| 2-4-74 | 7:50 AM | 16° | -13° | -.15 | -.16 |
| 2-6-74 | 8:00 AM | 44° | +28° | +.37 | +.38 |
| Bearing No. 4 Location: E. Abut S. Brg. Ramp C | | | | | |
| 1-30-74 | 1:56 PM | 62° /2 | - | - | - |
| 1-31-74 | 8:50 AM | 44° | -18° | -.12 | -.09 |
| 2-1-74 | 7:45 AM | 29° | -15° | -.27 | -.22 |
| 2-4-74 | 7:50 AM | 16° | -13° | -.14 | -.10 |
| 2-6-74 | 8:00 AM | 44° | +28° | +.39 | +.35 |

1/ Differential movement from each preceding reading, (+) Expansion, (-) Contraction
2/ Temperature of girder in shade.

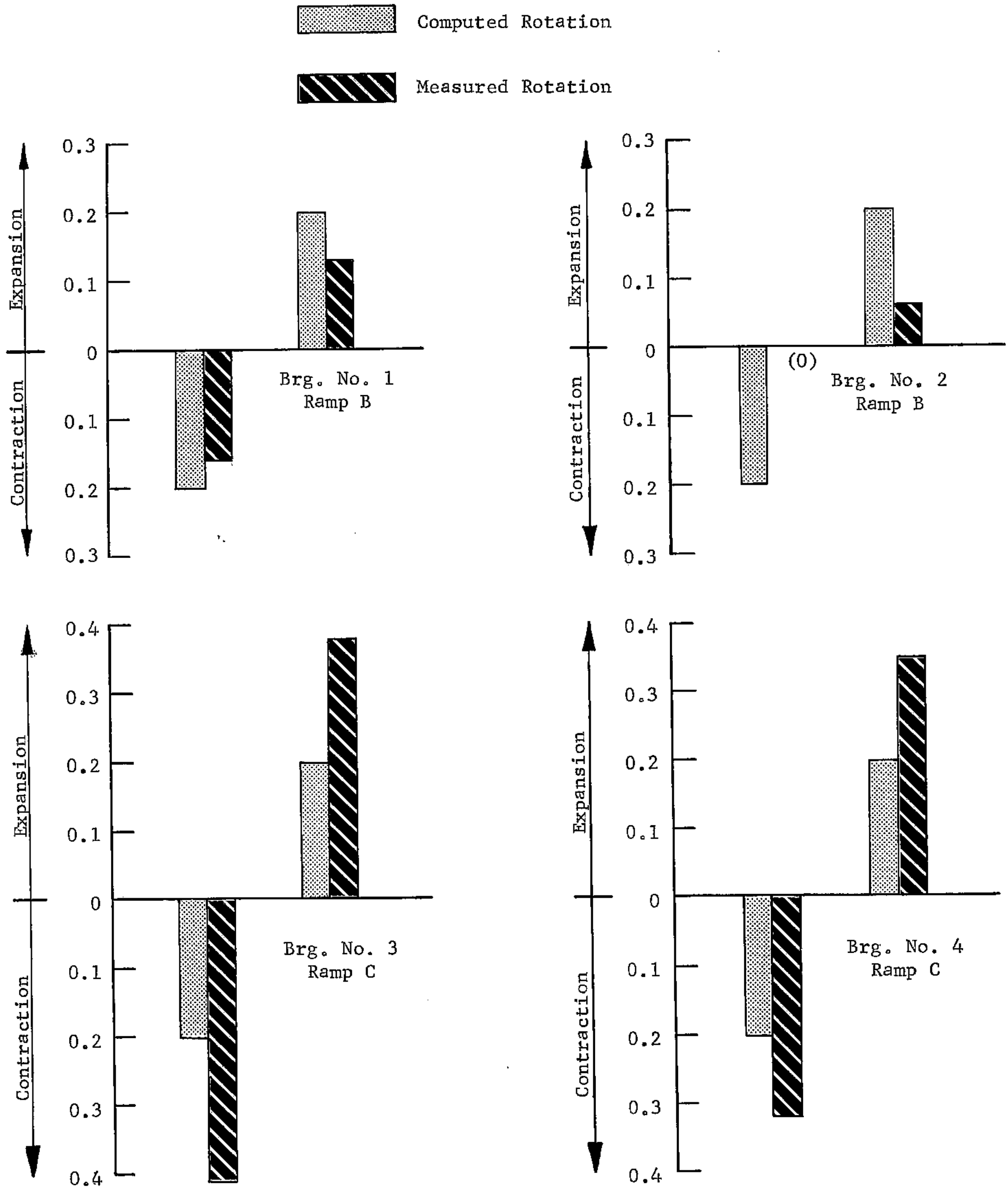



Figure 3. Measured rotation versus computed rotation.

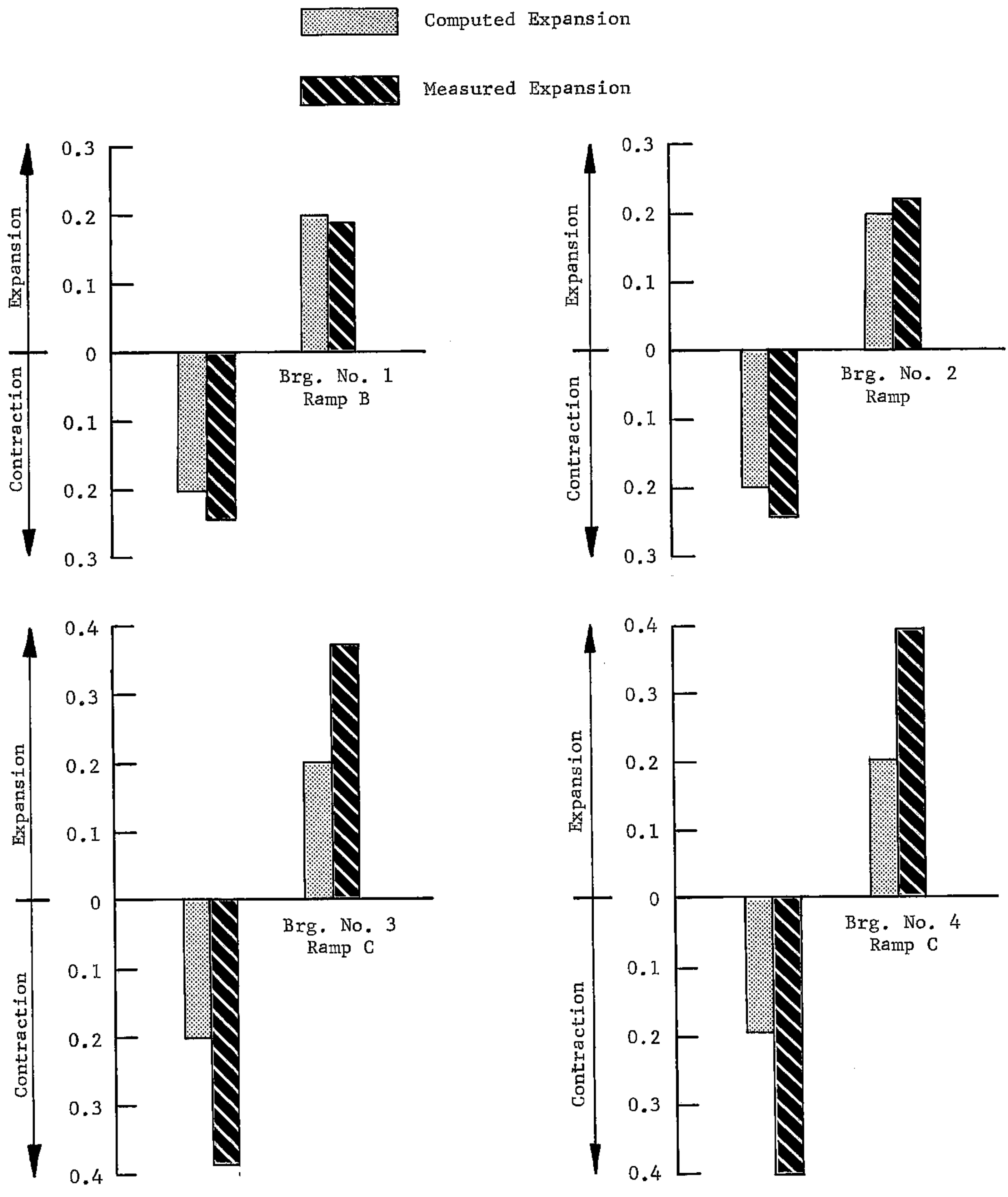



Figure 4. Measured expansion versus computed expansion.

The measured rotations of the bearings No. 3 and 4 at Ramp C correspond favorably with the expansion measurements, which indicate that these bearings are free to rotate under normal temperature changes. The data also show that the measured rotations and expansions are approximately twice the theoretical values based on a 90 ft expansion length from the adjacent fixed pier. This difference between the theoretical and measured values may have resulted from some movement occurring at the fixed pier.

The results of this preliminary field study supported the visual observations previously reported by the Bridge Inspection Team of the Bureau of Maintenance. On the basis of their report and of the findings from this preliminary study, it was concluded that a large majority of bearings were seized and that the same problem may likely occur at many of the remaining bearing locations.

Laboratory Test

At first, it was believed that the bearing seizure might be directly related to the radius of curvature of the girders and possibly to eccentric vertical loads induced by torsion at the ends of the girders. A series of 1/3 size model bearings were fabricated to determine if the seizure was related to either or a combination of both excessive high loads applied vertically to the bearing or misalignment of the bearing relative to the direction of expansion (Figure 5).

The first test was performed by applying a series of vertical loads through the top of the bearing assembly. Loads were applied in increments to a maximum which produced a unit bearing pressure of 33 ksi on the surfaces in contact with the pin and the saddles supporting the pin. The horizontal forces required to rotate the bearing were measured for each of the corresponding increments of applied vertical load. The results of the test are plotted on Figure 6.

The plot shows a reasonably uniform increase in the horizontal force for applied vertical pressures up to 22.5 ksi. Beyond this point, there was sharp increase in the

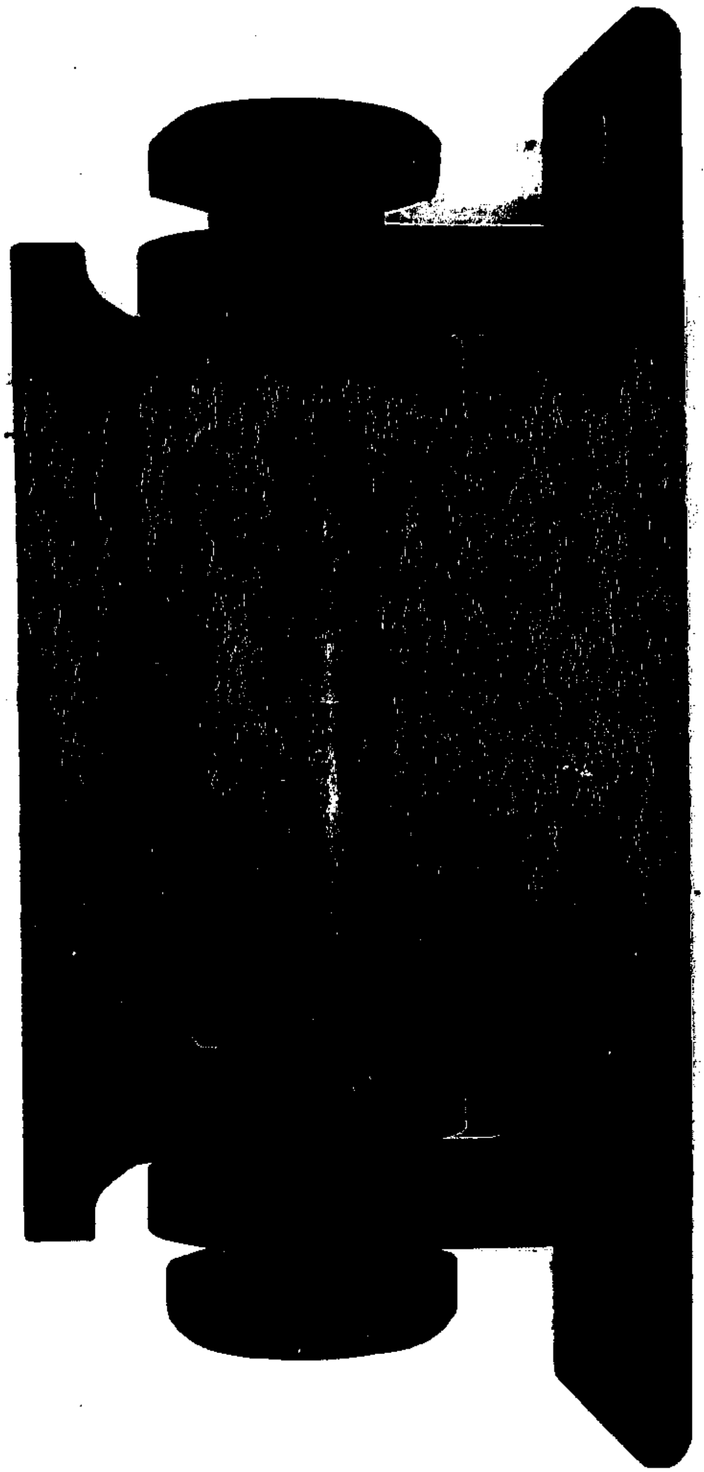


Figure 5. A 1/3 size model of bearing used on Poplar Street Complex.

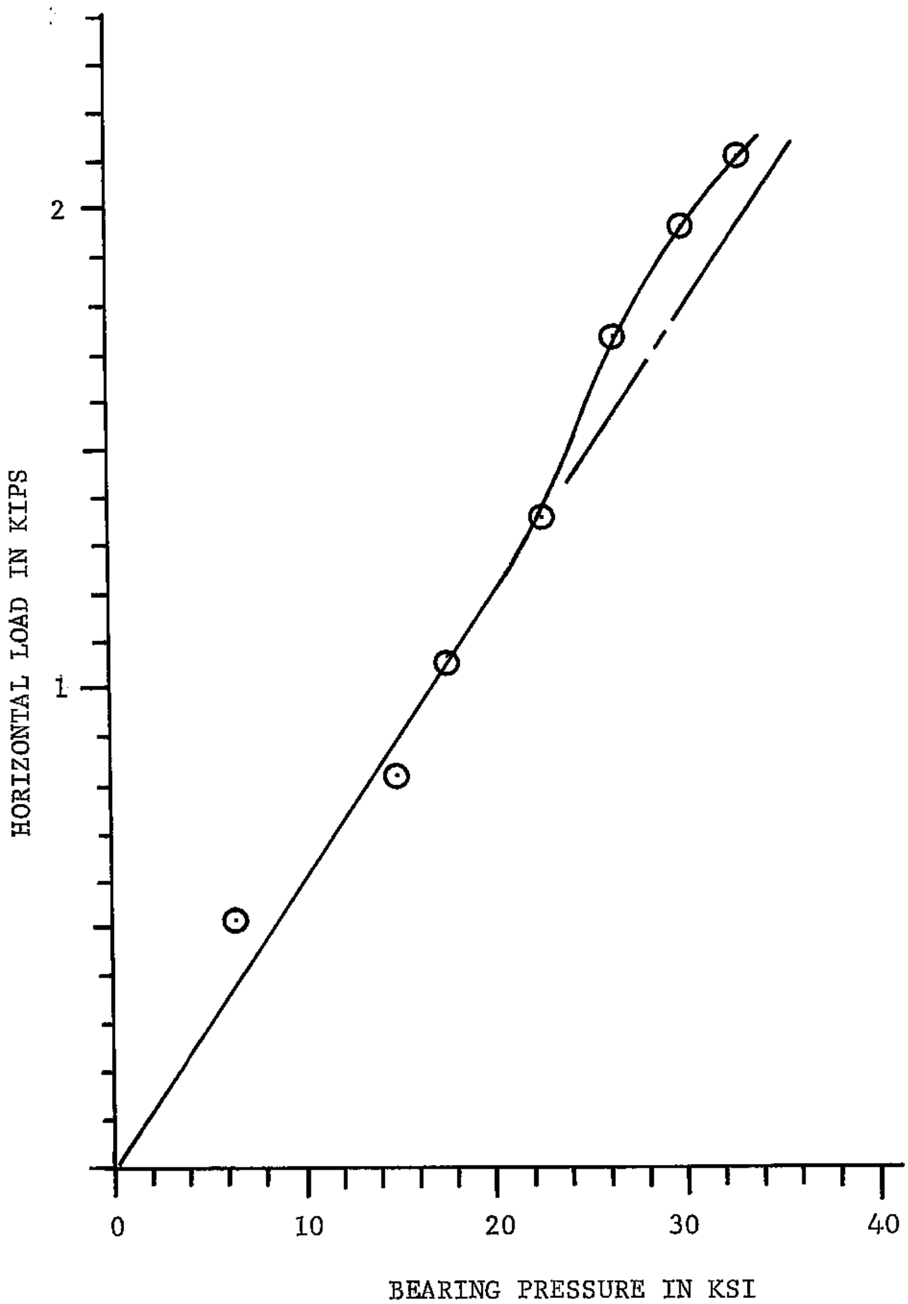



Figure 6. Results of vertical load test of 1/3 size model bearing.

horizontal force required to rotate the bearing. Examination of the pin after completing the test had revealed evidence of galling on both the pin and the saddle as shown in Figure 7 and 8. The galling had produced a build-up of hard, solid material which had a tendency to lock the pin to the supporting saddle.

A second 1/3 size model was tested to determine the effect of skewing the bearing relative to the direction of motion. A hard grade steel pin was used in order to reduce the influence of galling. The data from the test show a 15 to 16 percent increase in the longitudinal force from a $0^{\circ}$ to $5^{\circ}$ skew under normal working bearing stresses from 10 ksi to 15 ksi (Table 3). From observations of the model bearing under test, a $5^{\circ}$ skew in the alignment of the bearing did not appear to be a critical factor in the behavior of the bearing.

Because of the galling that had occurred during the first test, a second phase of experimentation with model bearings was implemented to find a combination of materials that would eliminate or reduce the effect of galling. This phase consisted of cyclic test of four 1/4 size models utilizing mild and case hardened steel pins with and without the use of a lubricating agent.

The first test involved the use of an unlubricated mild steel pin of the same material composition used for the bearings on the Poplar Street Complex. After 2000 cycles and under a normal load of 10 ksi, the pin and the saddle had shown severe signs of galling or wear, which is shown as specimen T-1 in Figure 9.

A second test under the same loading pressure, 10 ksi, was conducted with the use of an identical mild steel pin that was case hardened. The amount of wear experience with the case hardened pin was not significant after 2000 cycles of rotational movement (T-2, Figure 9). As a matter of interest, the test had shown also that the coefficient of friction of the case hardened pin was only slightly lower than the coefficient for the mild steel pin with no surface treatment (Figure 10).

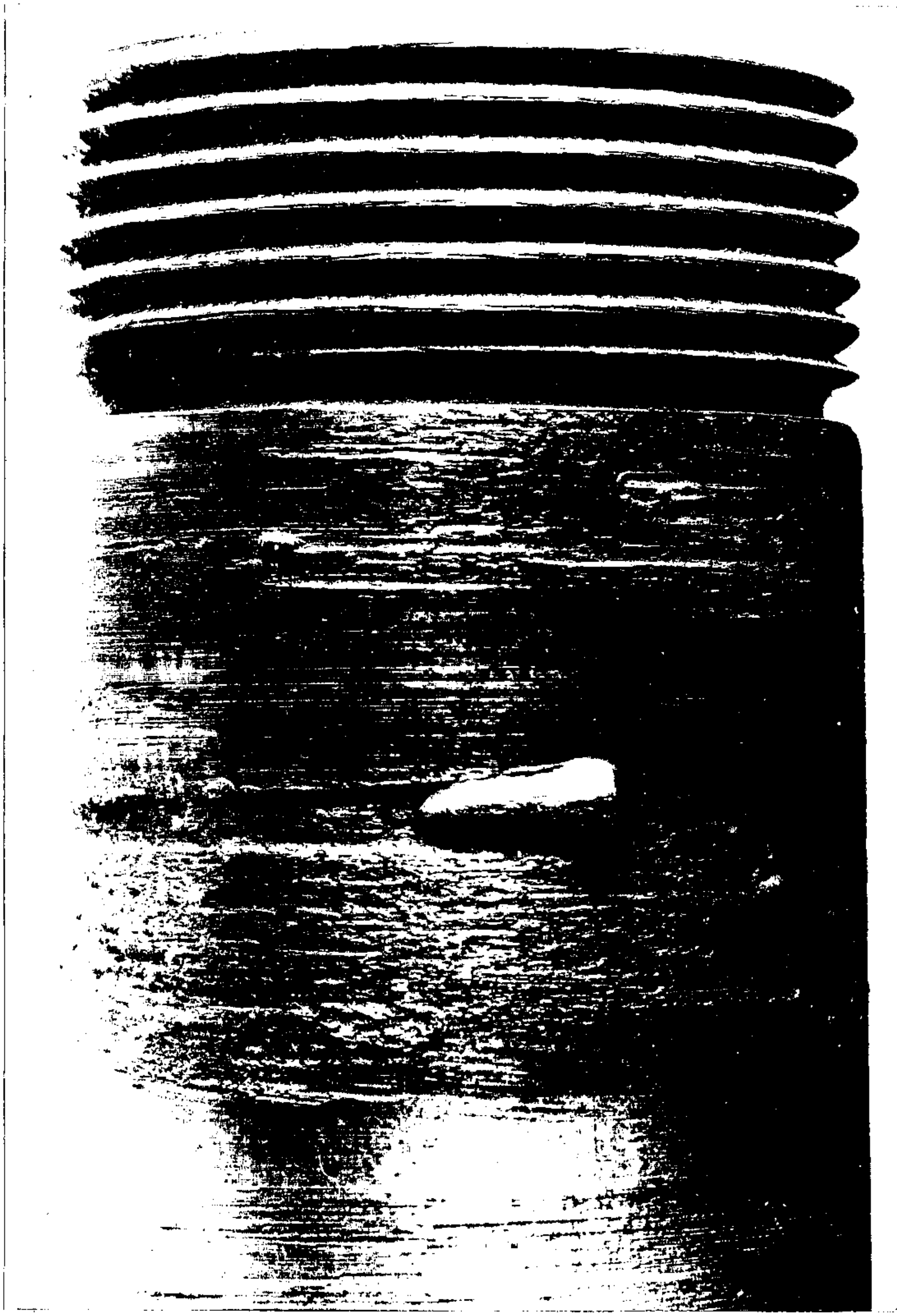


Figure 7. Pin of 1/3 size model bearing showing evidence of galling.

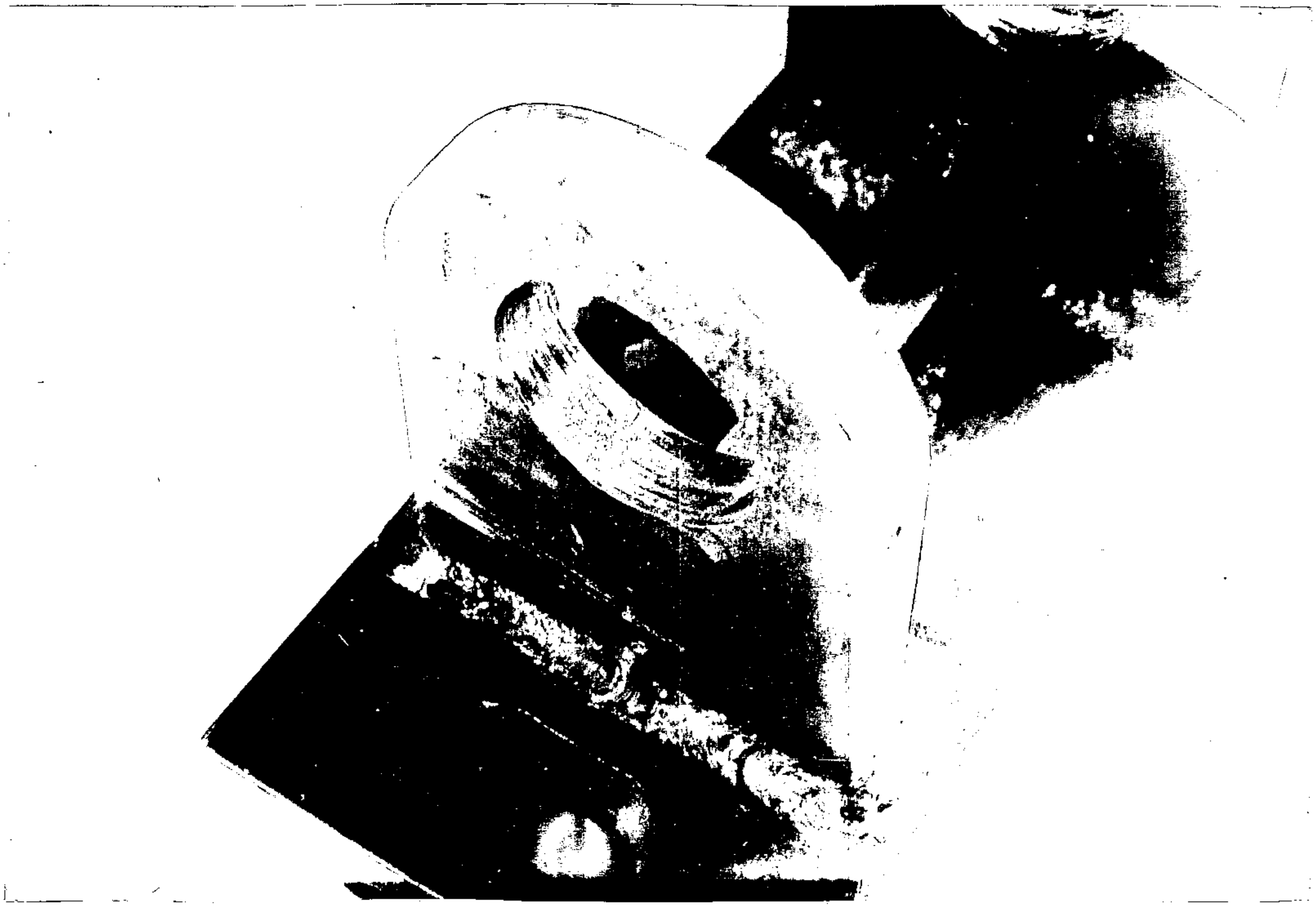


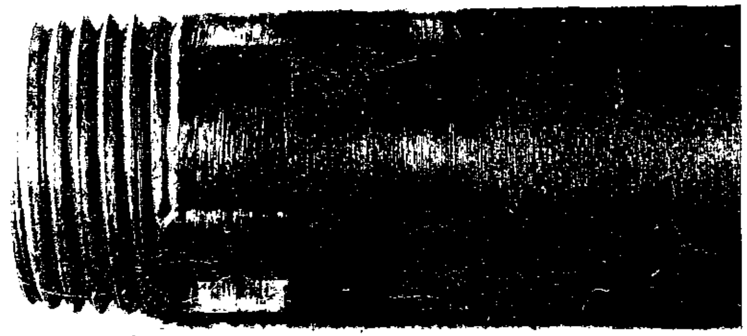
Figure 8. Saddle of 1/3 size model bearing showing evidence of galling.

TABLE 3

PERCENT INCREASE IN LONGITUDINAL LOAD DUE TO 5° SKEW - HARD GRADE STEEL

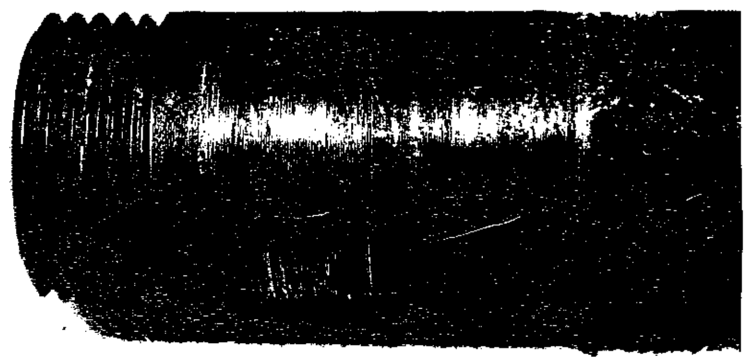
| Vertical Load KSI | Skew Angle 0° $F_h/F_v$ | 5° $F_h/F_v$ | Percent Increase |
|---|---|---|---|
| 5 | .067 | .084 | 25 |
| 10 | .057 | .066 | 16 |
| 15 | .052 | .060 | 15 |
| 20 | .051 | .055 | 10 |

T-1 Mild Steel (Dry)



T-2 Case Harden (Dry)

T-3 Mild Steel (Greased)



T-4 Case Harden (Dry Lub.)

2000 Cycles at 10 KSI

Figure 9. Test specimens after cyclic test.

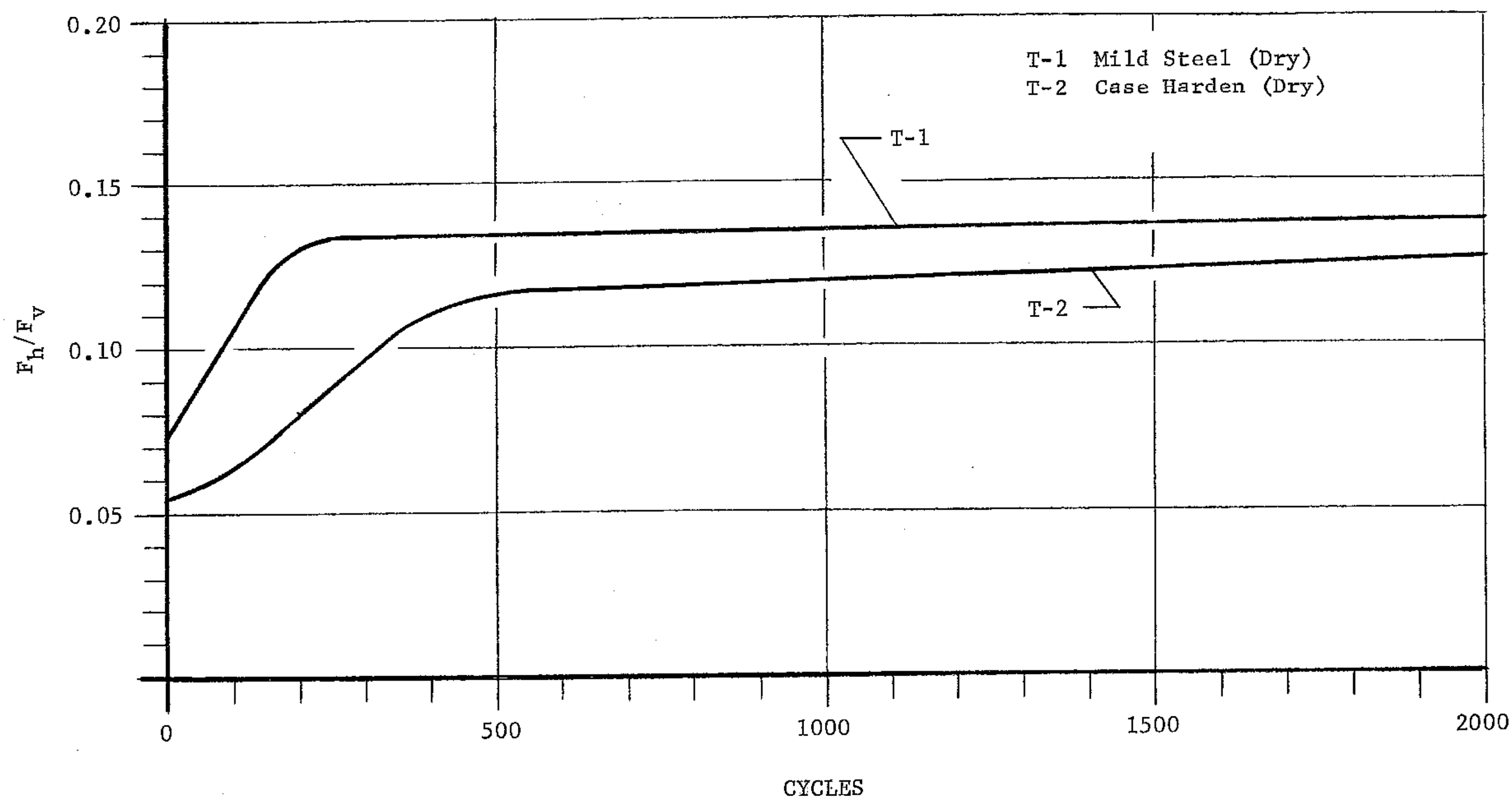



Figure 10. Coefficient of friction of dry, mild and case hardened pins.

A third specimen which was tested under the same conditions was a mild steel pin with no surface treatment but lubricated with a heavy duty grease. After 2000 cycles, galling to some extent was evident as shown in Figure 9 as T-3. However, the galling was limited to only a small area at one location on the pin. Although galling had occurred to a slight degree, the coefficient of friction of the pin with the grease lubricate was constant throughout the test and was about one-third of the coefficient obtained without the use of the grease lubricant (T-1 Figure 10 and T-3 Figure 11).

A fourth test was conducted using a case hardened pin with a dry film lubricant. The results of the test showed little or no benefits in the use of this type of lubricant (T-4, Figures 9 and 11).

Conclusions derived from this series of tests indicate that a pin with a case hardened surface and the use of a grease-lubricant would be highly beneficial as a means of improving the behavior and life expectancy of a pin connected type bearing.

Experimental Elastomeric Bearings

On the basis of the laboratory tests, it appeared that the effect of loading and the angle of orientation may not have been major factors contributing to the seizure of the bearings. The seized bearing from Ramp B at the east abutment was removed and replaced to determine if there were other factors related to the seizure (Figure 12). The bearing on the opposite side also was replaced so that thermal movements at the east end of the structure could be monitored.

The bearings used for replacing the steel bearing assemblies were elastomeric bearings reinforced with steel laminates. The overall dimensions of the bearings were 12 in. x 18 in. x 5 in. (Figure 13).

The ends of the girders were instrumented to determine the normal direction of thermal movement at the ends of the girders. The instrumentation consisted of a painted glass plate mounted on the bottom flange at the ends of the girders and a

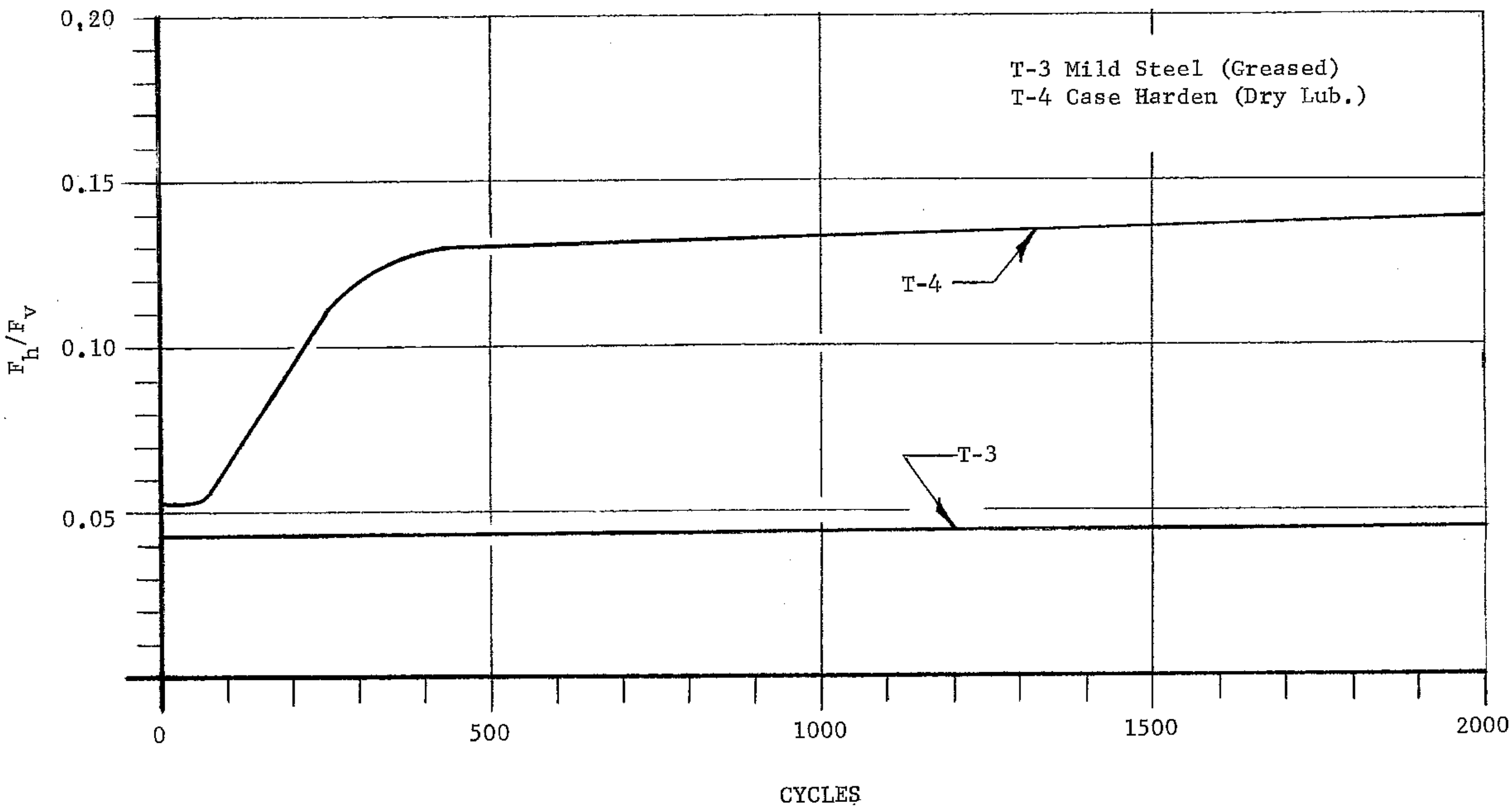



Figure 11. Coefficient of friction of lubricated, mild and case hardened pins.

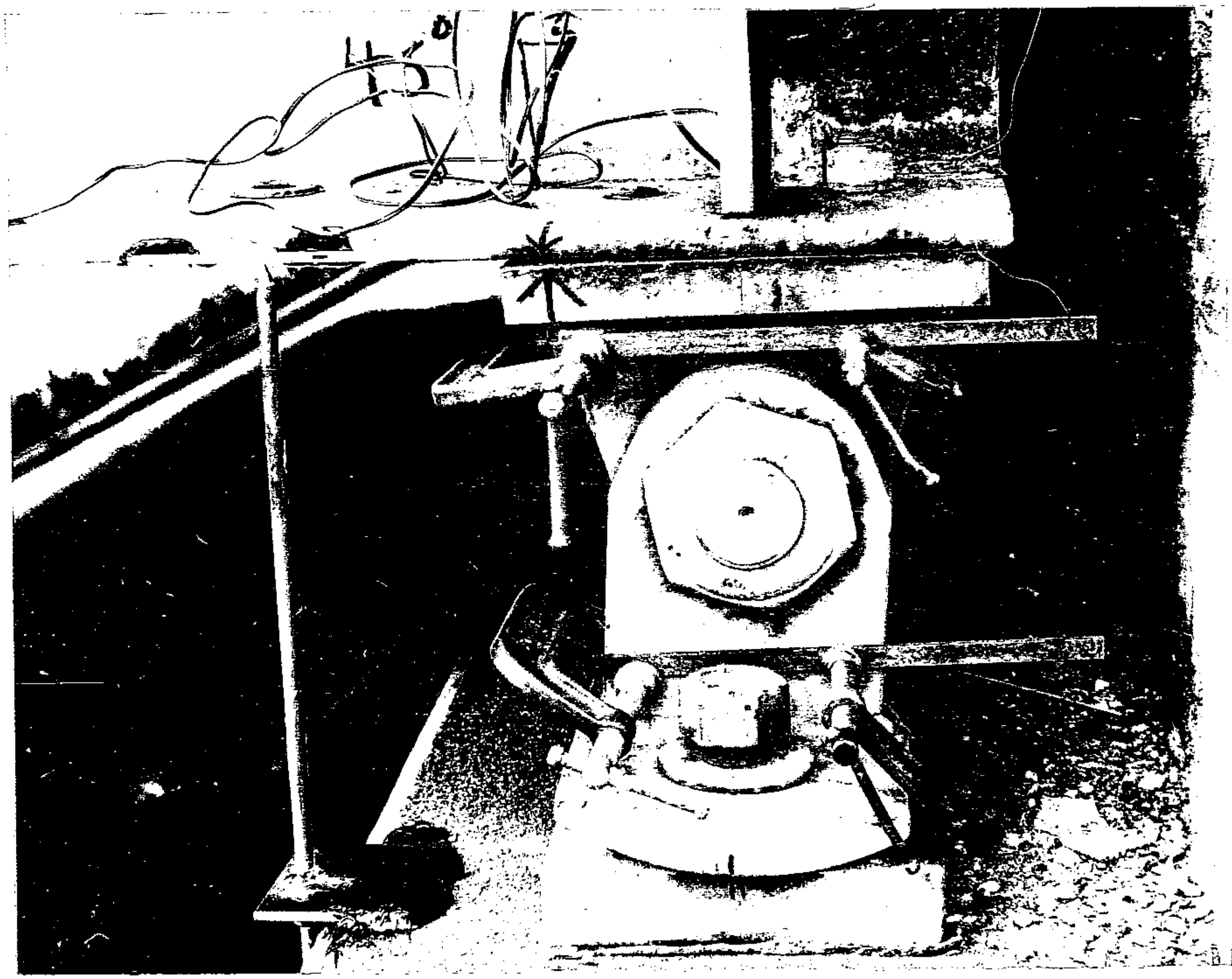


Figure 12. Pin connected steel bearing assembly before removal from structure.

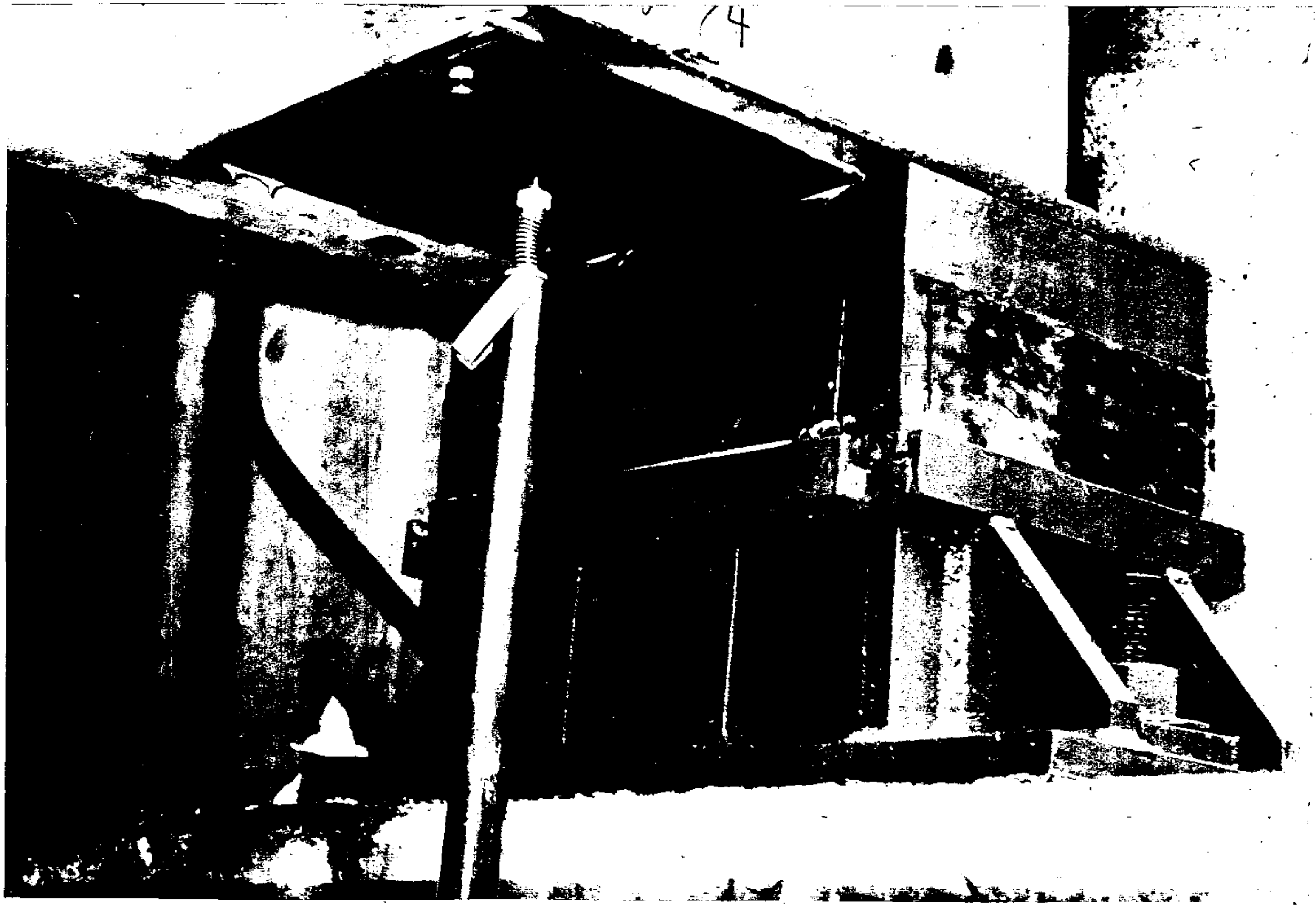


Figure 13. Experimental elastomeric bearing and instrumentation for detecting thermo movements.

pointed scribe mounted on the abutment cap (Figure 13). The movements of the girders near the bearings were recorded on the plate by the scribe which served as a stationary reference.

Theoretically, the motion at the end of a curved girder should be parallel to a chord from the point of fixity to point of expansion. This is based on the assumption that all elements within the unit are free to expand with no points of restraint imposed upon the unit. However, in the case of continuous curved girders incorporating bearings that are limited to unilateral movement, restraining forces can develop at the bearing points. Unpredictable movements may occur as a result of these restraining forces.

The bearings on the Poplar Street Complex were set tangent to the radius at the point of bearing. The plate shown in Figure 14 represents movements that have occurred during a temperature range from $61^{o}F$ to $11^{o}F$ or a differential of $50^{o}F$. The direction of movement recorded at the experimental bearings was about $4^{o}$ from the tangent to the radius at the point of bearing. The angle of the tangent with respect to the chord through the fixed bearing at the adjacent pier is about $1^{o} - 30'$. In this case, the direction of movement deviated approximately 2.7 times the theoretical angle. This discrepancy may be due to distortion of the structure by restraining forces developed within the system of steel bearings used for the Complex. It is of interest to note that the general direction of the longitudinal thermal travel appears to be along a line parallel to the chord between the ends of the continuous girders of the 3-span continuous unit.

On the basis of the laboratory tests, it is believed that the angle of placement relative to the direction of expansion is sufficiently small to not have a significant effect on the performance of the type of bearing originally used on the Complex.

Inspection of Steel Bearing Assemblies

The steel bearing assemblies that were removed were cut open to expose the contact


Figure 14. Glass plate showing thermal movement at elastomeric expansion bearing.

surfaces of the pin and the supporting saddles (Figures 15, 16, 17, and 18). A layer of highly compacted rust was found on the contact surfaces of the pin and the saddles. Parts of the specimens shown in Figure 11, 17 and 18 were submerged in a rust dissolvent. The solution used reacts only with rust and does not attack sound metal. Over 95 percent of the material that was removed had dissolved in the solution. It was concluded that the seizure of the bearing was directly related to the accumulation of rust that had formed on these surfaces.

The steel bearing assemblies that were removed had been in service for only six to seven years. Considering the short period of time for rust to form and freeze the pin connected bearing, it appears that a bearing of a different design such as the elastomeric type would provide better service.

Visual inspection of the exposed surface areas of the above specimens that were cleaned with the rust dissolvent did not reveal severe signs of galling as previously observed on the laboratory specimens. The absence of galling indicates that the formation of rust was probably the major factor contributing to the seizure of the bearing.

The pin has a 3½ in. diameter and a clearance of 1/50 in. with respect to the bored diameter of the pin holes in the assembly. The narrow clearance between the pin and the bored holes may have influenced the short duration of time required for sufficient rust to accumulate and freeze the bearing.

Specimens of larger pins removed from much older structures and subjected to larger rotational movements have shown that the combination of galling and rusting can eventually freeze a bearing before reaching the normal life expectancy of a structure.

A typical specimen is represented in Figure 19. The pin shown in the figure was removed from a bearing assembly of a truss built in 1937 (Figure 20). The structure

Figure 15. Pin removed from bearing assembly of Poplar Street Complex.

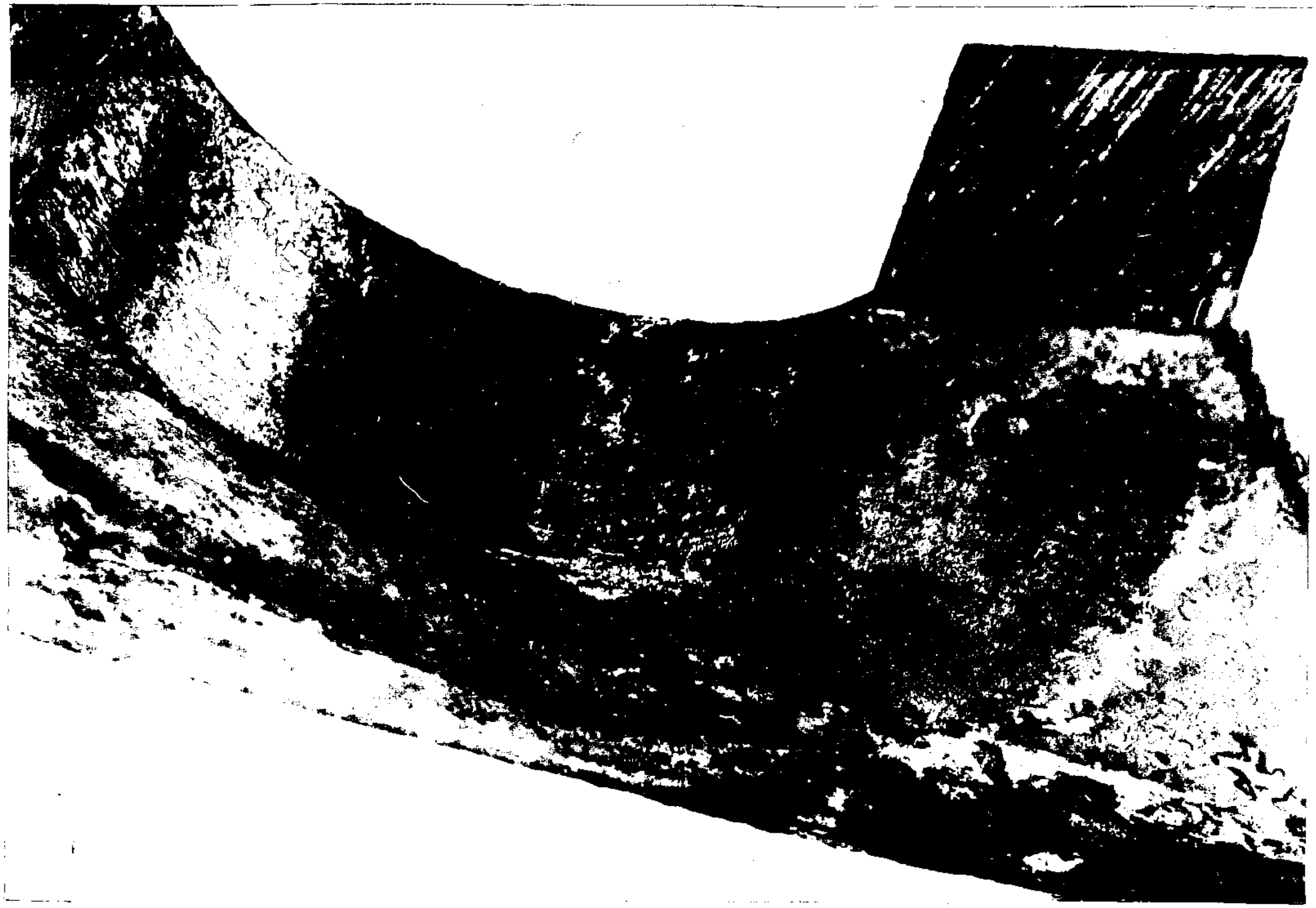


Figure 16. Specimen removed from saddle of bearing assembly of Poplar Street Complex. (Specimen No. 1)

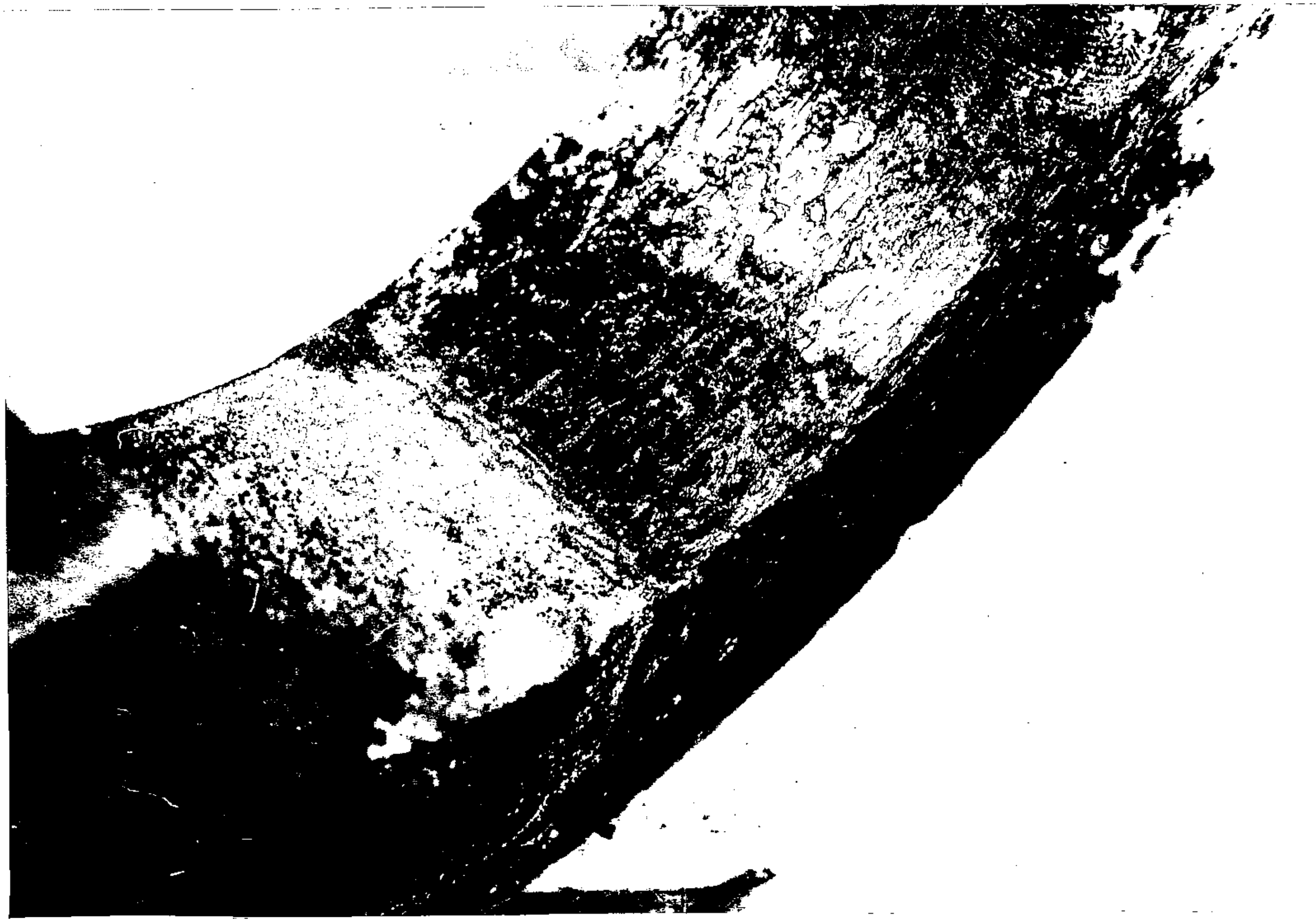


Figure 17. Specimen removed from saddle of bearing assembly of Poplar Street Complex. (Specimen No. 2)

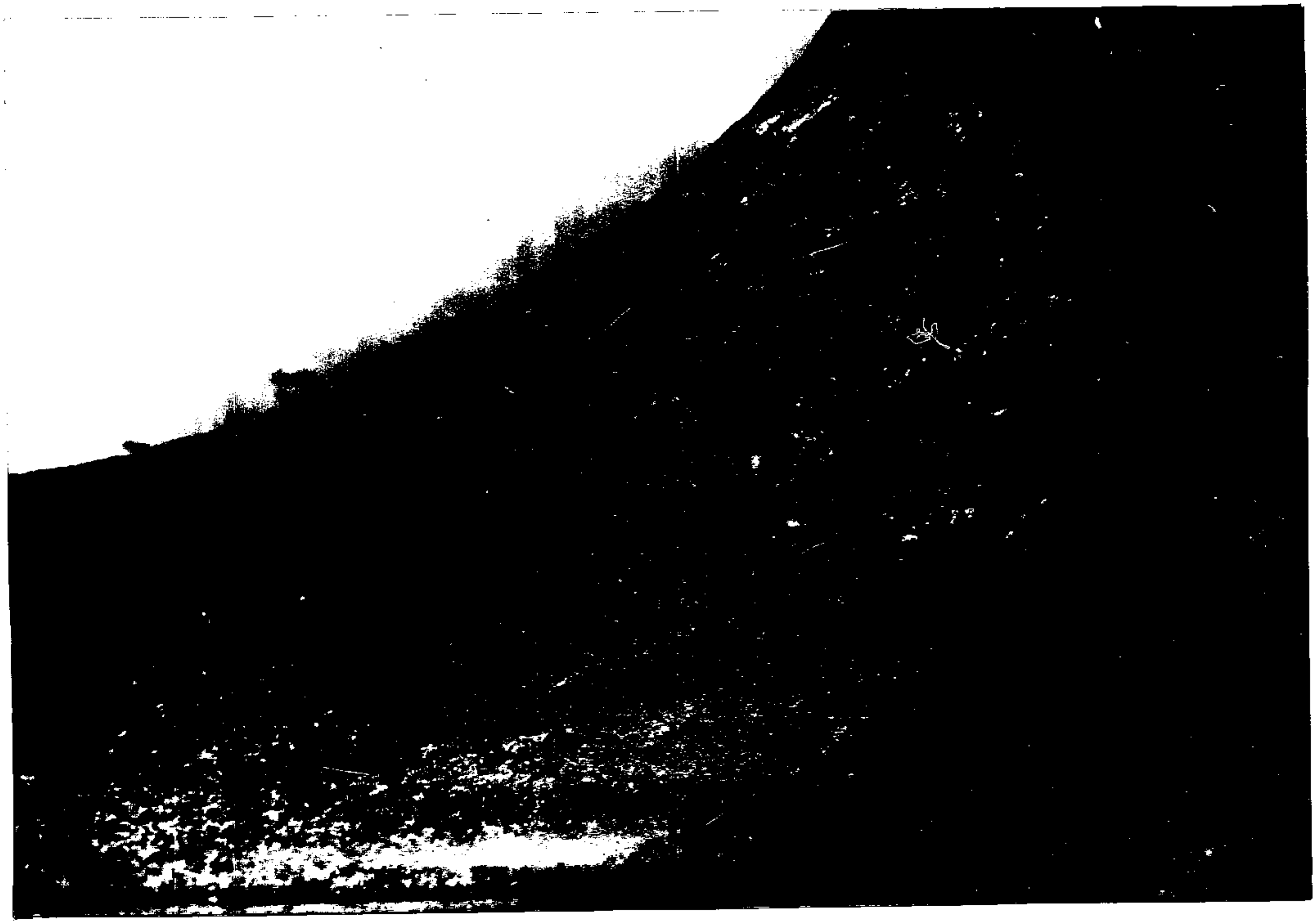


Figure 18. Specimen removed from saddle of bearing assembly of Poplar Street Complex. (Specimen No. 3)

Figure 19. Pin removed from bearing assembly of Lacon Bridge.

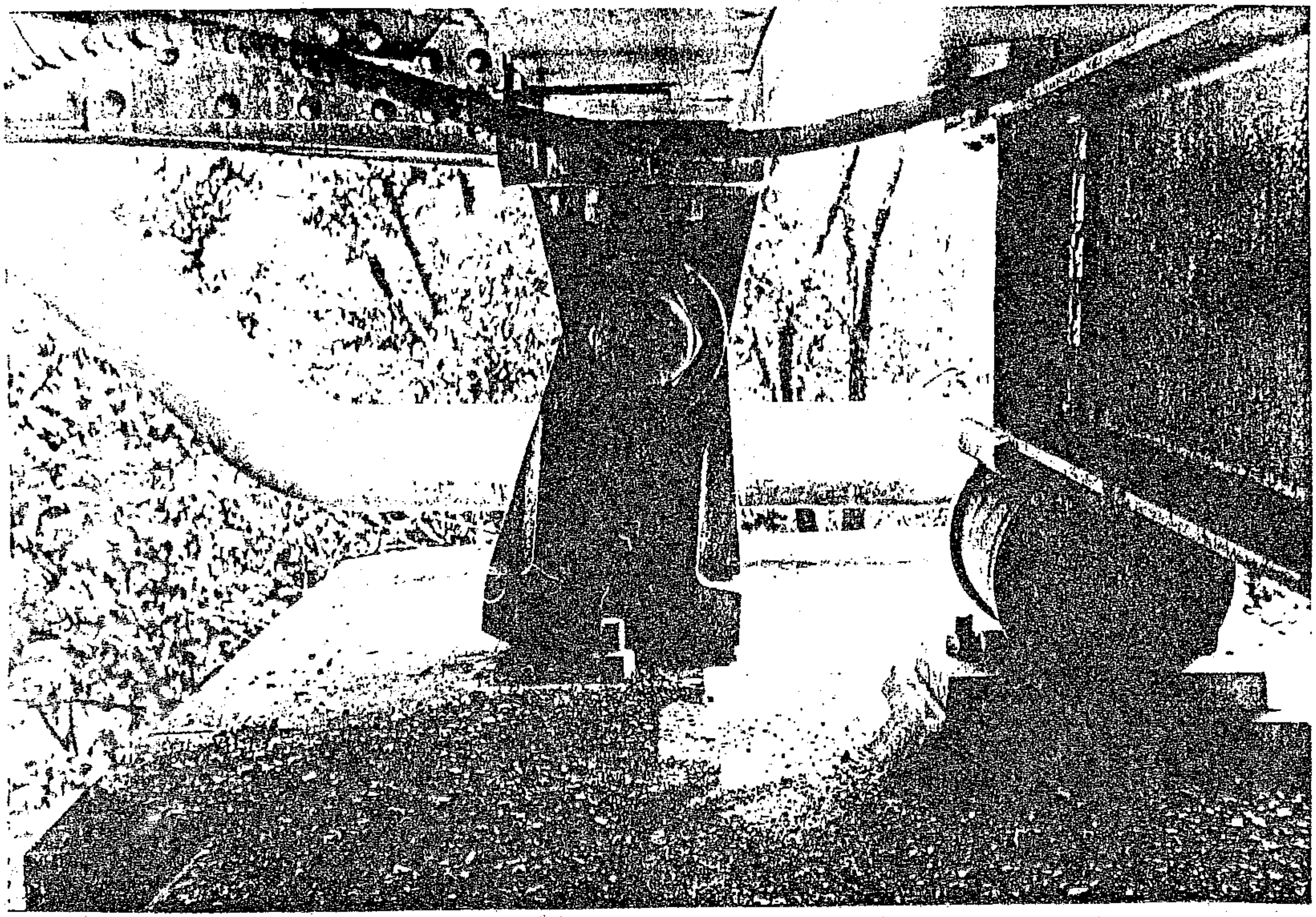


Figure 20. Pin connected bearing assembly from Lacon Bridge.

is identified as the Lacon Bridge over the Illinois River, SBI 90, Section 1-B. Marshall County. The bridge has a design expansion length of 700 ft from the fixed bearing to the location of the pin-connected expansion bearing. A photograph of the bearing assembly is shown in Figure 20.

The diameter of the pin is 5½ in. for which a clearance of 1/32 in. between the pin and the saddle is normally specified. The additional clearance provided for the larger pin may be a factor that may have extended the service life of the bearing assembly, beyond that of the bearings used on the Poplar Street Complex.

Seizure of the bearing had become apparent during an inspection in the fall of 1971. Signs of localized distress were found which were directly attributed to the seized bearings (Figure 21). The bearing assemblies supporting the truss have steel clip angles connecting the top bolster of the assembly to the lower chord of the truss. An exceptionally wide crack had formed completely through the clip angle as shown on Figure 21.

Unsuccessful attempts to free the bearing in place were made by the State maintenance forces of the Bureau of Maintenance. Penetrating oils were applied and an attempt was made to force grease into the contact areas through holes drilled into the housing. Since the bearing could not be freed in place, a decision was made to remove the bearing assembly so that it could be restored to a working condition.

The assembly was placed in a 300-ton press to determine the load required to rotate the assembly about the pin. The press did not have sufficient capacity to free the pin from the frozen condition. The load was applied longitudinally to the bearing in the direction of normal travel.

The holes in the top and bottom bolsters were rebored and a new pin was fabricated for the assembly. The housing was equipped with grease fittings and the pin was case hardened to alleviate the effect of galling. Recessed grooves were also machined into the pin in line with the grease inserts to provide a means of dispersing the grease around the pin. This procedure was suggested on the basis of the findings of laboratory tests.

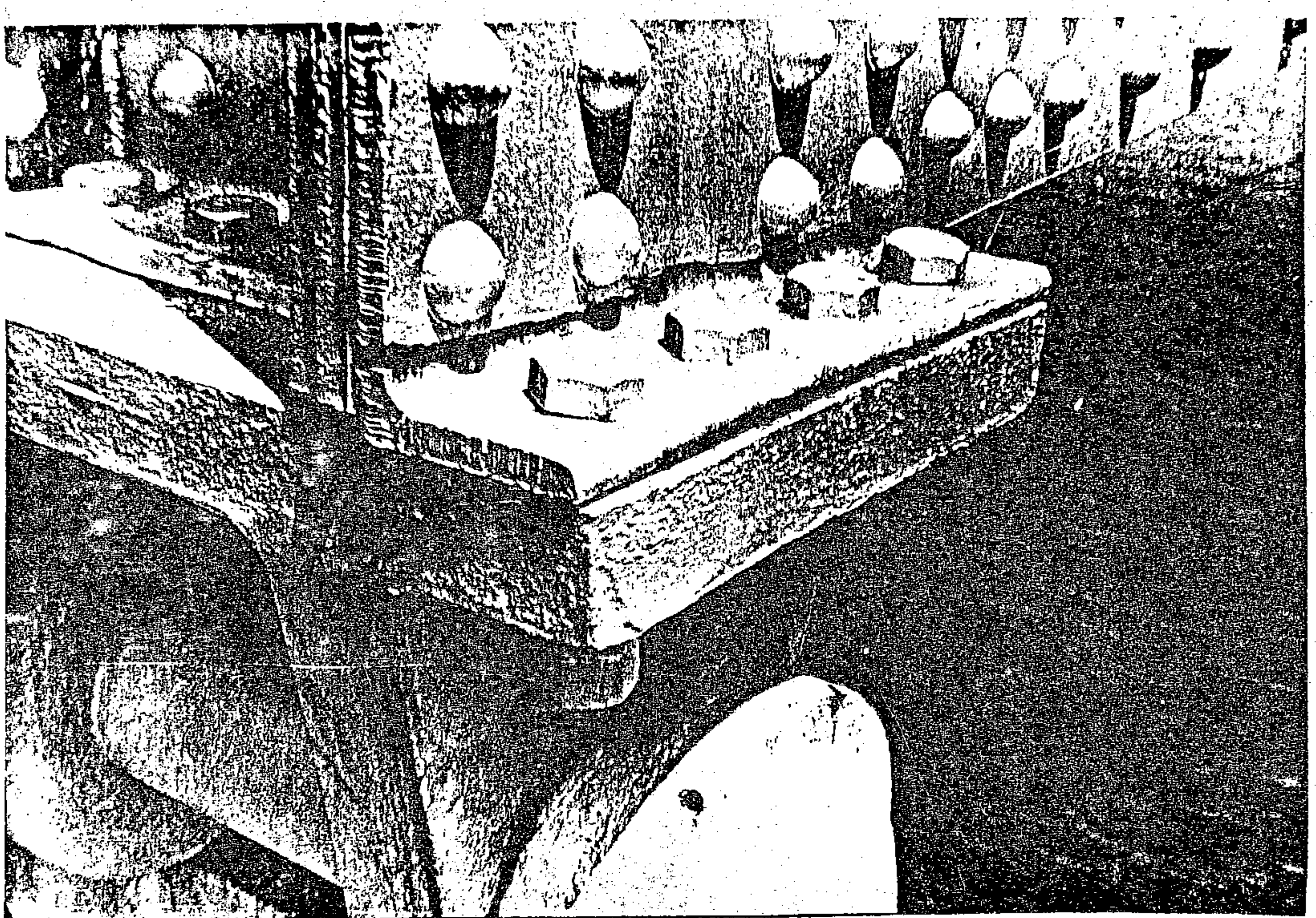


Figure 21. Localized distress found on clip angle of Lacon Bridge.

CONCLUSIONS

The seizure of the pin connected steel bearings for the Poplar Street Bridge was directly related to the presence of rust that had accumulated between the contact areas of the pin and the supporting saddles. Pins removed from seized bearings of an older structure have shown also similar evidence of rust, in addition to severe signs of galling of the pin.

Laboratory tests of model bearings show that the performance or life expectancy against galling could be substantially increased by using a case hardened steel pin and by lubricating the assembly with a heavy duty grease. A grade SAE 8620 steel which is heat treated to produce a case hardening to a depth of .12 to .15 in. with a surface hardness of 58 HRC is recommended for the pin. The case hardening should be excluded from the threaded portions of the pin.

The use of elastomeric, TFE elastomeric, or elastomeric-pot type bearings is suggested for future designs when the direction of thermal movement is undefined or nonlinear, or when transverse rotational freedom is needed to reduce unwarranted or undefined torsional stresses developed at the ends of the girders.

The problems associated with the Poplar Street Complex indicate a need for further research on two-girder systems. Although this investigation was primarily concerned with the problems related to the steel bearing assemblies, a second mode of distress was observed at several locations that was directly related to the connecting plate which attached the diaphragms or floor beams to the main girders. Cracks within the web were found near the top of the fillet weld that connects the web to the bottom flange of the girder. The cracks were located just below the point of contact between the connecting plate and the web. In one case the crack was about 19 in. long (Figure 2).

The attachment of the end floor beam is a rigid connection with the connecting plate welded to the web of the girder. The bottom of the connecting plate is coped to miss the fillet weld between the bottom flange and the web, and is milled to have a tight fit at the bottom flange. The connecting plate near the bearing supports is also located about seven inches from the center line of the bearing and the bearing stiffener. Because of the transverse moment induced at the connecting plate and the torsional resistance produced by the steel bearing assembly, a localized concentration of stress is developed in the web near the fillet weld of the bottom flange.

In view of the distressed areas found, a comprehensive investigation should be made of the torsional stresses induced within the main girders of two-girder systems under all modes of loading, and of the interaction between the diaphragms and the girders with emphasis placed on developing design details that would eliminate the type of distress found on the Poplar Street Complex. The investigation should include both straight and horizontally curved girder systems, having both open and closed framing.

## RECOMMENDATIONS

On the basis of this investigation, the following recommendations are suggested:

### Bridges Under Design

1. The use of pin-connected type details subjected to rotation and utilizing corrosive mild steels should be avoided when possible. Consideration should be given to the use of Elastomeric, TFE-Elastomeric, or Elastomeric-Pot Type bearings in the design of new structures.

### Bridges Under Construction

1. For bridges under construction without structural steel in place, consideration should be given to revise the design to incorporate a case hardened pin, grease retaining grooves in the pin, and grease inserts in the bearing housing, or to

substitute a design which incorporates an elastomeric type bearing. In the case of plate girders, additional bearing stiffeners should be also provided at the ends of the girders when using the pin-connected type steel bearing.

2. For bridges under construction with structural steel in place, consideration should be given to provide grease inserts in the bearing housing. In the case of plate girders, additional bearing stiffeners should be also provided at the ends of the girders.

Bridges Under Maintenance

1. For bridges with bearings that are subjected to large movements and that appear to have free movement, consideration should be given to provide grease inserts. In the case of plate girders, additional bearing stiffeners should be also provided at the ends of the girders.
2. For bridges with bearings that are subjected to large movements, that do not appear to move freely, and that show no signs of distress, consideration should be given to provide additional bearing stiffeners at the ends of the plate girders. Other types of structures should be evaluated on an individual basis which may depend on the type of structure, on the nature of the structural details within the bearing area, and on the potential for failure in the area of the bearing.
3. For bridges with bearings that are subjected to large movements, that do not appear to move freely, and that show signs of distress, consideration should be given to removing the bearing and reworking the assembly as outlined as item 1 under "Bridges Under Construction" or replacing the bearing with a different design. In the case of plate girders, additional bearing

stiffeners should be also provided at the ends of the girders when using the pin-connected type bearing.

General

1. The above recommendations generally pertain to expansion bearings at the ends of continuous units utilizing plate girder sections for the main supporting members. With special consideration, the same basic procedure may be applicable for other types of structures.
2. Case hardening of a mild steel pin with a medium carbon content may be acceptable as a minimum requirement. However, a grade SAE 8620 steel which is heat treated to produce a case hardening to a depth of .12 to .15 in. with a surface hardness of 58 HRC would be preferred. The case hardening should be excluded from the threaded portions of the pin.
3. Research work will continue to determine a possible alternate procedure for freeing seized bearings in place. It is conceivable that a seized bearing could be freed in place by submerging the pin and the surrounding contact areas of the housing in a solution of rust dissolvent. Experimentation with this procedure should be completed before the end of 1975.